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# HAZARDOUS MATERIAL ANALYSIS AND CODING SYSTEM (HAZMACS)



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OPERATIONS RESEARCH AND ECONOMIC ANALYSIS OFFICE

DEPARTMENT OF DEFENSE
DEFENSE LOGISTICS AGENCY

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FOREWORD

This report documents the development of an operational expert system for hazardous material classification. The Hazardous Material Analysis and Coding System (HAZMACS) is a personal computer (PC) based expert system which can be used by depot receiving personnel and others to assign a Hazardous Characteristic Code (HCC). The HCC represents a new coding system which will provide critical information needed to effectively manage, store and ship hazardous materials. Because these codes must be assigned quickly and accurately, HAZMACS is considered to be a key element in the implementation of the new HCC coding system. Although HAZMACS is now a freestanding system, it is envisioned that the system could eventually be embedded within, or otherwise linked to, the Defense Logistics Agency (DLA) depot mainframe computer system. Efforts to implement HAZMACS have already begun. A Working Group has been formed and an Implementation Plan of Action has been drafted.

ROGER C ROY
Assistant Director
Policy and Plans

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## ACKNOWLEDGMENTS

We wish to express our gratitude to several individuals whose invaluable assistance contributed immeasurably to the success of this project. We believe that the Hazardous Material Analysis and Coding System (HAZMACS) reflects credit upon them and their organization. We would like to thank Mr. Russell H. Van Allen, Chief of the DoD Hazardous Material Data Bank Branch, Defense General Supply Center (DGSC-SSH), who made it possible for members of his staff to assist us in the development and validation of the HAZMACS rule bases. Additionally, on more than one occasion, Mr. Van Allen's professional opinion helped to resolve key issues pertaining to the approach taken in developing the expert system. Thanks also go to Mr. J. Frank Adams of DGSC-SSH who, although his involvement came during the latter stages of rule base development, brought a fresh and practical perspective to the project.

We would especially like to thank Dr. Fred J. Tramontin of DGSC-SSH for his support and perseverance throughout the development of HAZMACS. Dr. Tramontin consistently and unselfishly gave of his time and expertise, beginning with the prototype and continuing through the last four HCCs for radioactive material. Clearly, his efforts made a difference in the quality of HAZMACS.

## EXECUTIVE SUMMARY

The Defense Logistics Agency (DLA) Depot Operations Division, Directorate of Supply Operations (DLA-OW), is implementing a new hazardous material classification system consisting of 55 Hazardous Characteristic Codes (HCC). The HCC provides critical information needed to effectively manage, store and ship hazardous materials.

With implementation of the new DLA Warehousing and Shipping Procedures (DWASP) system, DLA depot receiving personnel will be required to assign the HCC if it is missing from pertinent documents. Without the HCC, DWASP will not assign a depot storage location. Because a high degree of accuracy is essential in selecting the correct storage location and determining appropriate handling procedures, an expert system approach appeared to offer the best means for assisting depot personnel in performing this task.

The purpose of this project was to develop a freestanding, operational expert system which can quickly and accurately assign HCCs. Accordingly the Hazardous Material Analysis and Coding System (HAZMACS) was developed. HAZMACS is a personal computer (PC) based expert system which queries the user about the known characteristics of suspected hazardous material. Expert systems are computer programs which emulate the problem solving processes of "human experts." Therefore, the questions which HAZMACS asks and the "rules of thumb" it uses were developed with the able assistance of DoD hazardous material specialists. As a result, HAZMACS is capable of assigning all 55 HCCs listed and defined in DLAM 4145.11, Appendix B, Storage and Handling of Hazardous Materials, 1988.

Although this freestanding system obtains all of its input information from a human user, it is envisioned that the system could eventually be embedded within, or otherwise linked to, the DWASP mainframe computer system, obtaining its input via electronic data transfer from vendors to DLA.

Efforts to implement HAZMACS have already begun. An Implementation Working Group has been formed and a Plan of Action has been drafted. The DLA Operations Research and Economic Analysis Office is represented on this working group and is providing technical assistance to DLA-OW under the separate project DLA-XX-10070, HAZMACS Implementation. The first step in implementing HAZMACS will consist of rigorous testing by both technical experts and end-users. Future tasks and responsibilities addressed in the Plan of Action include system documentation, user training, fielding and maintenance of the expert system.

# I. INTRODUCTION

## A. Background

The Depot Operations Division, Directorate of Supply Operations (DLA-OW) is implementing a new hazardous material classification system consisting of 55 Hazardous Characteristic Codes (HCC). The HCC provides critical information needed to effectively manage, store and ship hazardous materials. Under current Defense Logistics Agency (DLA) methods, a hazard code is assigned by trained chemists and chemical engineers employed at the Department of Defense (DoD) Hazardous Material Data Bank Branch (DGSC-SSH) located at the Defense General Supply Center (DGSC). However, with implementation of the new DLA Warehousing and Shipping Procedures (DWASP) system, DLA depot receiving personnel will be required to assign the HCC if it is missing from pertinent documents. Without the HCC, DWASP will not assign a depot storage location. The HCC assignment would be subject to later review by DGSC-SSH.

Because of the wide range of hazardous materials received and the variety of shipping and handling documentation which may accompany those receipts, it may be very difficult for depot personnel to classify this material without some kind of ongoing technical support. Because a high degree of accuracy is essential in selecting the correct storage location and determining appropriate handling procedures, an expert system approach appeared to offer the best means for providing this technical support to depot personnel in a consistent and coherent manner.

Accordingly, under a separate project (DLA-89-P81022), the DLA Operations Research and Economic Analysis Management Support Office (DORO) had developed a prototype Hazardous Material Analysis and Coding System (HAZMACS). The prototype, which could assign 10 HCCs, demonstrated the feasibility of using Artificial Intelligence/Expert System (AI/ES) technology to assist depot personnel in assigning the HCC. Nevertheless, because of the size and complexity of the prototype, DORO had concluded that the application software package used for the prototype would not be appropriate for an operational expert system. Subsequently, however, DORO completed an independent assessment of the expert system software package VP-Expert and concluded that the development of a personal computer (PC) based production expert system for HCC assignment was both feasible and advisable using VP-Expert.

B. Purpose. The purpose of this project was to develop a freestanding, PC-based, operational expert system which could quickly and accurately assign all 55 HCCs. Although this freestanding system obtains all of its input information from a human user, it is envisioned that the system could eventually be embedded within, or otherwise linked to, the DWASP mainframe computer system, obtaining its input via electronic data transfer from vendors to DLA.

C. Objectives.

1. To develop a PC-based expert system for HCC assignment utilizing the VP-Expert software package.

2. To design the expert system so as to minimize user interaction through the use of menus and "yes or no" options and develop the rule base to insure consistency and completeness of input information.

3. To develop the expert system in distinct phases which correspond to the major hazardous material categories (e.g., Corrosives, Flammables, Poisons, etc.) to enable organized development and validation of the complete expert system.

4. To develop the expert system without placing inordinate demands on "human experts" by utilizing, to the extent possible, written definitions, regulations and other documentation to develop preliminary rule bases. The "human experts" could then be used primarily for testing and validation of interim versions of the expert system.

D. Scope. The expert system is designed to assign only those Hazardous Characteristic Codes listed and defined in DLAM 4145.11, Appendix B, Storage and Handling of Hazardous Materials, 1988.

E. Special Note. For the reader who is not familiar with artificial intelligence or expert systems, a glossary of terms is provided at Appendix A.

## II. DEVELOPMENT APPROACH

HAZMACS is a PC-based expert system which queries the user about the known characteristics of suspected hazardous material and assigns, if possible, an HCC based upon the user's responses. The general approach used in developing HAZMACS consisted of (1) acquiring domain knowledge in order to build a hazardous material knowledge base, (2) converting that knowledge base into an expert system rule base, and (3) testing and validation of the rule base. Both knowledge base development and expert system rule base testing and validation were accomplished with extensive support and assistance from trained chemists and chemical engineers employed at DGSC-SSH.

A phased approach was used to develop the expert system. Accordingly, knowledge acquisition, rule base development and system validation were accomplished in discrete segments consisting of distinct categories of hazardous materials (i.e., corrosives, flammable liquids, poisons, etc.).

The first step entailed the conversion of the original HAZMACS prototype system into a VP-Expert application. Conversion of the HAZMACS prototype was actually begun as part of the above referenced DORO assessment of the VP-Expert software package (see Section I.A.). When this conversion was completed, the VP-Expert version of HAZMACS was capable of assigning the following 10 primarily corrosive and flammable HCCs:

| Code | Hazard Group |
|---|---|
| C1 | Corrosive, DOT, Acid |
| C2 | Corrosive, DOT, Alkali |
| C3 | Acid, Low Risk |
| C4 | Alkali, Low Risk |
| D4 | Oxidizer and Corrosive |
| F6 | Flammable Liquid and Corrosive |
| F7 | Flammable Solid |
| J1 | Miscellaneous Flammable Liquids |
| J2 | Miscellaneous Flammable Solids |
| J6 | Miscellaneous Corrosive |

Subsequently, the expansion of the expert system rule base from the above 10-code capability to a capability to assign all 55 HCCs was accomplished in the following distinct phases:

A. Phase-I Expansion of HAZMACS. The rule base was expanded to enable HAZMACS to assign the following 19 HCCs for flammables, oxidizers, explosives and reactive materials. This was a logical first extension of the prototype expert system which already had the capability to assign some flammable and oxidizer codes.

| Code | Hazard Group |
|---|---|
| F1 | Flammable, Aerosol |
| F2 | Flammable, IMDG 3.1 |
| F3 | Flammable, IMDG 3.2 |
| F4 | Flammable, IMDG 3.3 |
| F5 | Flammable and Poison |
| F8 | Combustible Liquid |
| R1 | Reactive Chemical, Flammable |
| R2 | Water Reactive Chemical |
| D1 | Oxidizer |
| D2 | Oxidizer, Low Risk |
| D3 | Oxidizer and Poison |
| P1 | Peroxide, Organic, Regulated |
| P2 | Peroxide, Organic, Low Risk |
| J3 | Miscellaneous Oxidizers |
| J4 | Miscellaneous Organic Peroxides |
| J8 | Miscellaneous ORM-E |
| E1 | Explosive, Military |
| E2 | Explosive, Low Risk |
| N1 | Nonhazardous Material |

B. Phase-II Expansion of HAZMACS. The rule base was expanded to enable HAZMACS to assign the following 13 HCCs for poisonous material, infectious substances and miscellaneous hazards.

| Code | Hazard Group |
|---|---|
| T1 | DOT Poison-Inhalation Hazard |
| T2 | UN Poison, Packing Group I |
| T3 | UN Poison, Packing Group II |
| T4 | Poison, Food Contaminant |
| T5 | Pesticide Low Risk |
| T6 | Health Hazard |
| T7 | Carcinogen |
| J5 | Miscellaneous Poisons |
| K1 | Infectious Substance |
| K2 | Cytotoxic Drugs |
| J7 | Miscellaneous UN Class 9 |
| M1 | Magnetized Material |
| W1 | Marine Pollutant |

C. Phase-III Expansion of HAZMACS

The rule base was expanded to enable HAZMACS to assign the remaining 13 HCCs for gases and radioactive materials.

| Code | Hazard Group |
|---|---|
| G1 | Gas, (Non Flammable) Poison |
| G2 | Gas, Flammable, Non Toxic |
| G3 | Gas, Non Flammable, Non Toxic |
| G4 | Gas, Non Flammable, Oxidizer |
| G5 | Gas, Non Flammable, Corrosive |
| G6 | Gas, (Non Flammable), Poison, Corrosive |
| G7 | Gas, (Non Flammable), Poison, Oxidizer |
| G8 | Gas, Flammable, Poison |
| G9 | Gas, (Non Flammable), Poison, Corrosive, Oxidizer |
| A1 | Radioactive, Licensable |
| A2 | Radioactive, Licensable, Low Risk |
| A3 | Radioactive, License Exempt |
| A4 | Radioactive, License Exempt, Authorized |

At the end of each of the above phases, the client was requested to thoroughly evaluate the enhanced capabilities of HAZMACS and, once satisfied, to formally accept the expanded rule base.

The knowledge acquisition and rule base development activities employed for HAZMACS may have varied somewhat from a typical expert system development project. Throughout the development of HAZMACS, the project analysts made every effort to avoid placing inordinate demands on the domain experts at DGSC-SSH who have the important and exacting responsibility of maintaining the DoD Hazardous Material Information System (HMIS). Therefore, lengthy knowledge acquisition sessions between the project analysts and the domain experts were minimized by approaching each new category of hazards (e.g., poisonous material) in the following manner:

1. The project analysts obtained and reviewed pertinent manuals, handbooks and regulations.

2. The domain experts provided the project analysts with annotated copies of typical documentation (e.g., Material Safety Data Sheets, HMIS data extracts) used by the experts in analyzing and classifying items to be added to the HMIS.

3. Based upon their analysis of available documentation, the project analysts developed a preliminary rule base.

4. The preliminary rule base was then tested by the DGSC-SSH experts.

5. Corrections were made and the revised system was resubmitted to the experts. Steps 4 and 5 were repeated until the domain experts were satisfied with the accuracy of the expert system's HCC assignments.

III. RESULTS. HAZMACS consists of 14 separate Knowledge Base Files (KBF) containing more than 2200 rules and requiring approximately 700,000 bytes (700K) of memory. The 14 HAZMACS KBF include the Main Module and 13 hazard-specific KBF (e.g., corrosives.KBF, flammable-liquids.KBF). The user enters HAZMACS through the Main Module which then accesses or "chains to" one of the hazard-specific KBF based on the user's responses to several key questions.

A. Technical Accuracy of HAZMACS

At various stages throughout its development, HAZMACS was subjected to rigorous testing and validation by the domain experts. HAZMACS is very capable of accurately assigning all 55 HCCs encompassing the entire spectrum of hazardous materials now stored in DLA depots. The depth of analysis performed by HAZMACS varies from one hazard category to another. For instance, there are few examples of explosives in the HMIS and the domain experts at DGSC-SSH have limited experience in classifying these materials. In such cases, HAZMACS relies heavily on knowing the Department of Transportation (DOT) Hazard Class and/or the United Nations (UN) Hazard Class or Division. In some cases, the project analysts and the domain experts decided that it would not be practical to incorporate all of the knowledge of the experts within the expert system. Specifically, it was believed that questions pertaining to the "lethal dose" of poisons or the "specific activity" of radioactive material would be difficult to phrase clearly. There was concern that such questions could be misunderstood by end-users not familiar with these concepts which could lead to erroneous and possibly dangerous results. Accordingly, HAZMACS relies heavily on the presence of hazard labels or markings on packages or containers of poisons and radioactive materials.

In the majority of cases, however, HAZMACS performs a thorough analysis of each item of hazardous material. Where applicable, HAZMACS is concerned about quantitative measures such as the potential of Hydrogen (pH) of corrosives and the flash point of flammable liquids. In the absence of such quantitative data, an HCC assignment can often be made on the basis of a "packaging group" designation which indicates whether the item is considered to be a major, medium or minor transportation hazard. Typically, HAZMACS will look for clues about the item from its chemical name or proper shipping name. In many cases, a HAZMACS code assignment will depend on information provided by the user pertaining to incompatibility (i.e., materials to avoid) or reactivity (i.e., conditions to avoid).

B. User Friendliness of HAZMACS

Early in the development of this expert system it was decided that HAZMACS should always attempt to assign an HCC. Only in those instances where virtually nothing is known about the item in question or conflicting information has been provided, will HAZMACS be unable to assign an HCC. Accordingly, HAZMACS was designed for the user whose information may be limited to shipping papers and/or container labels or markings as well as the user who has access to the very detailed information contained in the manufacturer's Material Safety Data Sheet.

Although HAZMACS must obtain all of its input information from the user, all HAZMACS queries allow the user to either select from a menu of optional answers or simply respond yes or no. Typically, the experienced user can obtain an HCC assignment in two or three minutes. In conjunction with assigning an HCC, HAZMACS explains the rationale for that assignment. This feature provides a significant degree of quality control on the expert system's decisions, especially in the event the user makes a data entry error.

C. Lessons Learned. The following observations and comments are made primarily for the benefit of those organizations and/or individuals who may be contemplating the development of their first major expert system application.

1. Build a prototype first. Because of the heavy investment of personnel, computer and other resources that can be involved, expert system applications should be developed and implemented only where the technology is shown to be appropriate, where there is an acceptable level of risk, and where the benefits outweigh the costs of development. One means of achieving that goal is through the development of prototype systems. By developing the original 10-code HAZMACS prototype, we learned that it was feasible to solve the problem of hazardous material classification using this technology. However, we also concluded that, because of the size and complexity of the prototype, the software package used for the prototype would not be appropriate for an operational version of HAZMACS. It was not until the VP-Expert software package was made available that it became feasible for us to undertake the operational expert system project.

2. Keep the problem manageable in size. If we had known then what we know today, we may not have picked the problem of hazardous material classification as the subject of our first operational expert system project. Dating back to our development of the HAZMACS prototype, we were concerned about the magnitude of the problem and, therefore, the ultimate size of the expert system. Based on the size of the prototype, we knew that the operational expert system could require more than 2000 rules. Clearly, it would have been extremely difficult to develop the operational system as a single KBF, as would have been the case using the same software package that was used for the prototype system. Because VP-Expert allows one KBF to be accessed from another (i.e., "chaining"), we were at least able to keep the various pieces of the problem to a manageable size. Nevertheless, development of this expert system required a substantial investment in analyst resources. If HAZMACS offers any "rules of thumb" for determining the feasibility of future applications, it is that the development of an expert system (i.e., knowledge acquisition, rule base development, prototyping, and testing and validation) will require approximately 1.0 staff-hours per rule.

3. Never get too far ahead of your experts. Although we believe that HAZMACS demonstrates that an expert system can be developed without placing inordinate demands on "human experts", there are also pitfalls in using the development approach described in this report (see Section II). In trying to minimize the time needed of our experts, we sometimes relied too heavily on our own interpretation of regulations and other documentation. On occasion, therefore, when the experts were able to evaluate our interim rule bases, they found a substantial number of errors. In some cases, more time was required to correct rule base errors than was required to develop the initial, albeit erroneous, rules.

4. It may help if the experts are also the end users. This observation applies especially to first-time developers who are trying to identify the most appropriate process or activity to emulate in an expert system. As noted previously, HAZMACS was developed with the invaluable assistance of trained chemists and chemical engineers employed at DGSC. However, the intended users of HAZMACS are primarily wage-grade depot receiving personnel. This was the subject of some conflict from time to time during the development of the expert system. The domain experts saw no personal benefit from the expert system. It was not designed for their use nor did they believe they needed such a system. The system, in fact, was designed to allow someone with a high school education, or less, to perform a task which now is performed by college educated scientists and engineers. This idea, if not threatening to the domain experts, was somewhat unsettling. Fortunately for us, our experts did not let their personal skepticism interfere with their competent and professional support of this project.

IV. BENEFITS. The benefits and cost avoidances to be derived from HAZMACS are believed to include the following:

A. Accurate identification of hazardous materials leading to improved accuracy in selecting storage locations and reduced re-warehousing costs.

B. Better understanding by depot personnel of the characteristics of hazardous materials (including the existence of multiple hazards) resulting in safer storage and handling of materials and fewer accidents, spills, etc.

C. Avoidance of training costs that would otherwise be required to develop and maintain hazardous material "experts" at the various DLA depots.

V. IMPLEMENTATION. Implementation efforts for HAZMACS were initiated several months prior to the completion of the expert system. An Implementation Working Group was formed and has met several times. In addition to the client (DLA-OW), the technical experts (DGSC-SSH) and the expert system developers (DORO), Working Group members represent the Office of Information Systems and Technology (DLA-ZI), the DLA Systems Automation Center (DSAC), the Directorate of Technical and Logistics Services (DLA-SE), and the Operations Research and Economic Analysis Office (DLA-LO). The client has drafted a Plan of Action (POA) which delineates responsibilities and provides estimated completion dates for accomplishing the tasks required for implementation of the expert system. The first two steps in the POA are the development and implementation of a Test Plan for HAZMACS validation. The first phase of HAZMACS validation will consist of a technical accuracy evaluation involving a larger group of "domain experts" than were involved in the development of the expert system. The second validation phase will consist of end user testing conducted at one or more DLA depots. Other issues addressed in the HAZMACS POA include system documentation, user training, fielding and maintenance of the expert system.

VI. SUMMARY

A. The purpose and objectives of this project have been achieved.

1. HAZMACS is a freestanding, PC-based expert system which can quickly and accurately assign all 55 Hazardous Characteristic Codes listed and defined in DLAM 4145.11, Appendix B, Storage and Handling of Hazardous Materials, 1988.

2. HAZMACS is designed for the user whose information may be limited to shipping papers and/or container labels or markings as well as the user who has access to the very detailed information contained in the manufacturer's Material Safety Data Sheet.

3. Although HAZMACS must obtain all of its input information from the user, all HAZMACS queries allow the user to either select from a menu of optional answers or simply respond yes or no. Typically, the experienced user can obtain an HCC assignment in three minutes or less.

4. Although the methodology used in developing this expert system is not without its pitfalls, HAZMACS demonstrates that an expert system can be developed without placing inordinate demands on "human experts."

B. The following "lessons learned" during this project may be useful to others who may be contemplating the development of a major expert system.

1. Build a prototype first. This will help determine if it is feasible to undertake development of an operational expert system.

2. Keep the problem manageable in size. Large expert systems are very difficult to develop as a single KBF. Software packages which allow "chaining" of KBF can be helpful here. Expert systems can require substantial investments in staff resources. The development of HAZMACS suggests that a "rule of thumb" for determining the feasibility of future applications is 1.0 staff-hours per rule.

3. Never get too far ahead of your experts. From time to time, your experts may be too busy to talk to you. However, you may find that you are better off doing nothing than plunging ahead, assuming you know what the expert would say.

4. It may help if the experts are also the end users. If the expert system is not intended to be used by the "domain experts", then, obviously it is being developed to enable someone else to do the job of the experts. The experts may perceive little benefit to be derived from their involvement and may feel somewhat uneasy about the expert system.

## VII. RECOMMENDATIONS

A. DLA-OW should pursue the successful completion of those HAZMACS implementation efforts already begun. The Implementation Working Group should assist DLA-OW in accomplishing the Implementation POA.

B. As part of the DLA-OW POA, DLA-Z and DSAC should implement a Test Plan for HAZMACS validation at the earliest possible date. Any modifications or enhancements needed to improve the technical accuracy or user-friendliness of HAZMACS must be identified as soon as possible to avoid unnecessary delays in fielding the expert system.

C. At the earliest possible date and as part of the DLA-OW POA, DLA-Z and DSAC should resolve the issue of how HAZMACS will be maintained. Any obstacles to DSAC maintenance of the expert system should be identified as soon as possible so that solutions can be found or other maintenance alternatives identified.

APPENDIX A

## Glossary of Terms

Artificial Intelligence. The application of computers to problem solving processes or other activities normally thought of as requiring human intelligence. Artificial intelligence applications include expert systems, speech recognition and natural language interfaces, vision (image recognition), intelligent robotics and neural networks.

Expert Systems. Expert systems are computer programs which emulate a human expert's problem solving processes. They are used to provide advice when the human expert is not readily available, facilitate a task which requires a large number of interdependent steps, or replace the human decision maker in limited circumstances. Frequently, but not always, the knowledge of the human expert is represented within the expert system in the form of "IF-THEN" rules as in: "IF the forecast is rain, THEN I will take an umbrella."

Knowledge Acquisition. Knowledge acquisition, or knowledge engineering as it is also known, refers to the process and techniques used to capture the procedures, rules, and knowledge which must be incorporated within an expert system. This process is complex and generally requires significant learning and reasoning abilities as well as programming skills. In some cases, the knowledge engineer's role is limited to knowledge acquisition. Subsequently, the incorporation of this knowledge into an expert system is performed by a programming specialist.

Prototyping. Prototyping offers a means of evaluating the feasibility and possible benefits of a potential artificial intelligence (AI) application. It also serves to further define the intent of the system and the approach that is desired. AI projects, and especially expert systems, are often developed using a phased prototyping approach. First a small prototype is developed to show the basic intent and approach of the system. This "demonstration" prototype is expanded into a "research" prototype to add functionality and continue to evaluate the feasibility of the project. By continuing system expansion in this manner, the "research" prototype evolves into a "field" prototype, fully functional and suitable for testing by the end user.

# APPENDIX B

## HAZMACS End User Manual

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SECTION 1. GENERAL

1.1 Purpose of the End User Manual. This manual provides background information and instructions on the use of an expert system for hazardous material classification. The Hazardous Material Analysis and Coding System (HAZMACS) is a personal computer (PC) based expert system which can be used by Defense Logistics Agency (DLA) depot receiving personnel and others to assign a Hazardous Characteristic Code (HCC). The HCC represents a new coding system which will provide critical information needed to effectively manage, store and ship hazardous materials. Because these codes must be assigned quickly and accurately, HAZMACS is considered to be a key factor in insuring that hazardous material is identified correctly and, therefore, stored and handled properly.

1.2 Purpose of the System. HAZMACS was developed for the purpose of assigning all 55 HCCs listed and defined in DLAM 4145.11, Appendix B, Storage and Handling of Hazardous Materials, 1988. A complete list of the HCCs is also provided in Section 5 of this manual.

1.3 References.

a. Final Report, Hazardous Material Analysis and Coding System (HAZMACS), Project DLA-91-P00097, Operations Research and Economic Analysis Office, Headquarters, Defense Logistics Agency, May 1991.

b. DLAM 4145.11, Appendix B, Storage and Handling of Hazardous Materials, 1988.

1.4 Terms and Abbreviations. A glossary of terms and abbreviations used in this manual is provided in Section 6.

1.5 Distribution and Modification of HAZMACS. This expert system was developed in accordance with DLA requirements for standard Automated Information Systems (AIS). Distribution and modification of standard DLA AIS applications are controlled for the purpose of maintaining consistency of system performance and conformity to relevant agency policies. Unauthorized distribution, copying or modification of this expert system are strictly prohibited.

1.6 Regulatory Guidance. This manual has been developed in accordance with guidance for the preparation of end user manuals contained in the DoD Automated Information Systems (AIS) Documentation Standards, DoD-STD-7935A, 31 October 1988.

## SECTION 2. SYSTEM SUMMARY

### 2.1 Overview.

#### 2.1.1 Application Summary.

HAZMACS is a PC-based expert system which asks the user a series of questions about the known characteristics of suspected hazardous material and, if possible, assigns an HCC based upon the user's responses. Although the expert system must obtain all of its input information from the user, all of the questions which HAZMACS asks can be answered by either selecting from a menu of optional answers or simply responding yes or no. With a little practice, the user should be able to obtain an HCC assignment from HAZMACS in three minutes or less.

The questions which HAZMACS asks are based on the assumption that one or more of the following sources of information are available to the user:

- Material Safety Data Sheet
- Shipping Papers
- Department of Transportation (DOT) or International Shipping Labels
- Markings or Indicators

In addition, the user can obtain clarification of any question as well as hints on possible sources of information.

The depth of analysis performed by HAZMACS (and, therefore, the number of questions asked) will vary from one hazard category to another. In some cases (such as explosives), HAZMACS will be primarily concerned with knowing the DOT Hazard Class and/or the United Nations (UN) Hazard Class. In other cases (such as poisons or radioactive material), HAZMACS relies heavily on the presence of hazard labels or markings on packages or containers.

Wherever possible, HAZMACS will want to know if the degree of hazard can be measured. For example, if the user is trying to obtain an HCC assignment for a corrosive liquid, HAZMACS will ask if the user knows the pH of this material. Similarly, HAZMACS will ask the user if he or she knows the flash point of a flammable liquid. If this type of measurable data is not known or not available, HAZMACS can often make an HCC assignment on the basis of other information. For example, an item's packaging group will indicate whether the item is considered to be a major, medium or minor transportation hazard. Typically, the expert system will look for clues

about the item from its chemical name or proper shipping name. In many cases, a HAZMACS code assignment will depend on information provided by the user regarding materials to avoid (e.g., keep away from acids or oxidizers) or conditions to avoid (e.g., avoid exposing this material to heat or sparks).

HAZMACS will always try to assign an HCC. Only in those instances where almost nothing is known about the item or when conflicting information has been provided, will HAZMACS be unable to assign an HCC. Therefore, HAZMACS is designed for the user whose information may be limited to shipping papers and/or container labels or markings as well as the user who has access to the very detailed information shown on the manufacturer's Material Safety Data Sheet.

### 2.1.2 Performance.

HAZMACS consists of 14 separate Knowledge Base Files (KBF) containing more than 2200 decision rules and requiring approximately 700,000 bytes (700K) of disk space. Together with the VP-Expert software needed to run HAZMACS, the expert system requires approximately 1,000,000 bytes (1 megabyte) of disk space. The 14 HAZMACS KBF include the Main Module and 13 hazard-specific KBF. For example, there is a separate KBF for corrosives, one for flammable liquids, another for poisons, etc.

A session with HAZMACS is referred to as a "consultation." The user enters HAZMACS through the Main Module which then accesses or "chains to" one of the hazard-specific KBF, based on the user's responses to several key questions. When activating the expert system, the user must wait from 10-40 seconds (depending upon the hardware used) for the main module to load. Then after the user has been asked two or three key questions, he or she must wait another 10-40 seconds while the Main Module "chains to" one of the 13 hazard-specific KBF. This second "wait time" will depend on the size of the KBF being accessed by the Main Module as well as the hardware used.

After the second KBF is loaded, the user will be asked a series of questions designed to help HAZMACS make an HCC assignment. After all appropriate questions are asked, HAZMACS will display its results on the PC terminal. Those results will either show the HCC which HAZMACS has assigned or will indicate that HAZMACS was unable to make an HCC assignment. In either case, HAZMACS will display the information which the user provided, and which HAZMACS used, to obtain the results which are displayed. This feature can be helpful to the user in understanding the results reached by HAZMACS, especially in the event the user has made a data entry error.

After HAZMACS has displayed its results, the user is instructed to "Press any Key to Continue." The user can then obtain a printout of the expert system's results, if desired. Finally, the user can elect to return to the Main Module or stay in the current KBF. If the user elects to stay in the current KBF, he or she is reminded that HAZMACS will retain certain information in its memory from the consultation just completed. The only way to completely "clear" the expert system's memory is to return to the Main Module. If the user elects to return to the main module, a wait of 10-40 seconds will be required while the Main Module is loading.

## 2.2 System Environment.

### 2.2.1 Hardware Required.

HAZMACS was developed on a Zenith 248 PC with a 286 microprocessor. It has been successfully tested on an IBM PC, PC-AT and PC-XT. According to Paperback Software International, VP-Expert applications, such as HAZMACS, will run on IBM PCs, and most compatible systems, with 384,000 bytes (384K) of random access memory (RAM) and at least two disk drives. For HAZMACS, one of the disk drives must be a 5.25 inch double-sided floppy disk drive (needed to install HAZMACS); the other may be a fixed disk or RAM disk. If a RAM disk is used, however, HAZMACS is erased from memory each time the computer is turned off and must be reloaded when needed again. The HAZMACS application files will occupy approximately 1,000,000 bytes (1 megabyte) of fixed disk or RAM disk space. A printer is required for printed output. VP-Expert applications have been run successfully on IBM compatible computers from the following manufacturers:

| | |
|---|---|
| AT&T | Sharp |
| Compaq | Talbott |
| Epson | Tandy |
| Grid | Televideo |
| Hewlett-Packard | Toshiba |
| ITT | Vendex |
| NCR | Zenith |

The best performance achieved to date with HAZMACS occurred on a AST Premium 386/C PC. Load times for the Main Module and hazard-specific KBF were reduced to 10 seconds or less compared to the average 30 second load time on a Zenith 248 with a 286 microprocessor. Therefore, it is recommended that HAZMACS be run on an IBM compatible PC having at least a 386 microprocessor.

2.2.2 Software Required.

VP-Expert applications such as HAZMACS require DOS version 2.0 or higher. However, Paperback Software International indicates that VP-Expert may require more than 384K of RAM memory if DOS version 3.0 or higher is used. Additionally, VP-Expert may require more RAM memory if co-resident programs are used and may not run at all with certain co-resident programs.

The operational version of HAZMACS is referred to as the "runtime version." To enable the user to install HAZMACS from a single application disk, the majority of the HAZMACS runtime version files are in a compressed format. The application disk, therefore, appears to contain only the following files:

GO.BAT
INSTALL.TXT
HAZ.EXE
VPXHELP.CHP
INSTALL.BAT

However, the "install procedure" (see Section 3.1.1 Installation and Setup) will extract 17 files from the HAZ.EXE file and restore them to their normal size. After installation, the following 19 files (4 VP-Expert files and 15 HAZMACS files) will have been copied to your PC's fixed drive or RAM drive and will be occupying approximately 1 megabyte of disk space.

| | | |
|---|---|---|
| VPXRUN.EXE | - | VP-Expert Runtime System |
| VPX.MSG | - | VP-Expert External Text File |
| VPXHELP.CHP | - | VP-Expert Help Facility |
| VPXHELP.EXE | - | Calling Program for Help Facility |
| | | |
| GO.BAT | - | Activates HAZMACS |
| AHAZMAIN.KMP | - | HAZMACS Main Module |
| HAZCORR.KMP | - | HAZMACS Corrosives KBF |
| HAZETIOL.KMP | - | HAZMACS Infectious Substances KBF |
| HAZFLAMA.KMP | - | HAZMACS Flammable Aerosols KBF |
| HAZFLAML.KMP | - | HAZMACS Flammable Liquids KBF |
| HAZFLAMS.KMP | - | HAZMACS Flammable Solids KBF |
| HAZGASES.KMP | - | HAZMACS Gases KBF |
| HAZPOISN.KMP | - | HAZMACS Poisons KBF |
| HAZEXPLO.KMP | - | HAZMACS Explosives KBF |
| HAZMISC.KMP | - | HAZMACS Miscellaneous materials KBF |
| HAZOXID1.KMP | - | HAZMACS Oxidizer 1 KBF |
| HAZOXID2.KMP | - | HAZMACS Oxidizer 2 KBF |
| HAZOXID3.KMP | - | HAZMACS Oxidizer 3 and Org. Peroxide KBF |
| HAZRADIO.KMP | - | HAZMACS Radioactive materials KBF |

2.3 Assistance and Problem Reporting.

Any problems encountered with installing or operating HAZMACS should be reported to:

1. DLA Systems Automation Center
   Attn: DSAC-FFB,
   Defense Construction Supply Center
   Columbus, Ohio, AV 850-9190

   or,

2. DLA Operations Research and Economic Analysis Management Support Office
   Attn: Logistics Services Team,
   Defense General Supply Center
   Richmond, Virginia, AV 695-5199

Problems encountered with understanding HAZMACS questions or results should be reported to:

1. DLA Depot Operations Division
   Attn: DLA-OWP
   Headquarters, Defense Logistics Agency
   Cameron Station
   Alexandria, Virginia, AV 284-7541

   or,

2. DLA Operations Research and Economic Analysis Management Support Office
   Attn: Logistics Services Team
   Defense General Supply Center
   Richmond, Virginia, AV 695-5199

SECTION 3. ACCESS TO THE SYSTEM

3.1 First-Time Use of the System.

3.1.1 Installation and Setup.

Insert the HAZMACS application disk into Drive A of your PC. At the "A" prompt, type "INSTALL." The INSTALL command will create a directory on your "C" drive named HAZMACS. (Note: If you do not want this directory on your "C" drive, the INSTALL.BAT file will need to be modified accordingly.

You may wish to contact someone in your organization who is familiar with DOS or you may contact one of the organizations listed in Section 2.3 of this manual.) The remainder of instructions in this section of the manual assume that HAZMACS will be installed on your "C" drive.

All required files on the HAZMACS application disk will be copied into the HAZMACS directory (see Section 2.2.2 Software Required). In order to provide you with a copy of the HAZMACS expert system on one floppy disk, the majority of HAZMACS files are in a compressed format. However, the install procedure will extract and restore ("explode") these files to their normal size. You will, therefore, need approximately 1 megabyte (1000K) of disk space on your "C" drive. When installation is complete, the current directory will be changed to \HAZMACS. You should see the following prompt in the bottom left corner of your PC monitor screen:

C:\HAZMACS>

Remove the HAZMACS application disk from Drive A. Installation is complete.

## 3.2 Initiating a Session.

### 3.2.1 Main Module Operation.

If the current directory is not \HAZMACS, you will need to change directories at the "C" prompt by typing "cd\HAZMACS" (without the quotes). At the C:\HAZMACS> prompt, type "go" (without the quotes). Depending on the PC hardware you have, you must wait 10-40 seconds for the HAZMACS Main Module to load (about 30 seconds on a Zenith 248). The screen will identify this application as a VP-Expert Runtime Version and you will see the words "Loading File ..." on the left side of your screen.

After the Main Module has loaded, you will see a blank green screen and the following two levels of menu options at the bottom of your screen:

1Help 2Go 3WhatIf 4Quit
1Help 2How? 3Why? 4Quit

The top level is the "CONSULT" menu. Since the cursor (or light bar) is already on "2Go", the bottom level shows you the options that will be available on the "GO" menu. (You may want to move the cursor to "1Help," "3WhatIf" or "4Quit" to see how the bottom level of options changes.) The CONSULT menu is discussed in more detail in Section 4.1 of this manual.

Now, select "2Go" and press "ENTER." You will see the first HAZMACS Main Module screen which identifies HAZMACS as the Hazardous Material Analysis and Coding System and notes that HAZMACS helps to assign the correct HCC. Press any key to continue.

You will now see the second HAZMACS Main Module screen which indicates that you will be asked a series of questions about the item of hazardous material (or suspected hazardous material) which you are trying to classify. It is further noted that these questions are based on the assumption that certain sources of information are available to you. Press any key to continue.

The third HAZMACS Main Module screen points out that you can obtain clarification of any question as well as hints on possible sources of information by first pressing the "/" key and then selecting "Why." Press any key to continue.

The HAZMACS Main Module screen is now divided into two sections or "windows." The larger magenta top section is the "application display window." The smaller blue bottom section is the "question" or "query window." Several instructions appear at the bottom of the screen to remind you how to move the cursor, select from a menu of choices, quit, or indicate that the answer to a question is unknown. These instructions are explained in more detail in Section 4.1 of this manual.

The query window now instructs the user to "Select the DOT Hazard Class for this material." The user is also informed that this is the "First of Two Screens" meaning that two query screens are required to display all possible DOT Hazard Classes.

Before proceeding further, you may wish to become more familiar with one option on the "GO" menu. By pressing the "/" key, the following menu options now appear at the bottom of your screen:

1Help 2How? 3Why? 4Quit

This is the "GO" menu. With your arrow keys, select "3Why?" and press ENTER. You will now see a message displayed explaining why this question is being asked and suggesting where you may find the answer. The GO menu is discussed in more detail in Section 4.1 of this manual. Press any key to return to the first query screen.

At this time, you may wish to continue this HAZMACS consultation with your own "real" example of hazardous material. However, it may be beneficial for you to practice with a sample problem. Assume that, from shipping papers and container markings, you have the following information on an item for which you are trying to assign an HCC:

- the DOT Hazard Class is unknown
- the UN Hazard Class is Class 3 Flammable Liquid
- the product name is Acetone
- the flash point is -4 deg F cc
- the manufacturer warns that this material should be kept away from oxidizing material
- the item is packaged in ten 30 gal containers

Since the DOT Hazard Class is unknown, type "?" (without the quotes). The second DOT Hazard Class query screen now appears. Type "?."

The next query screen instructs you to "Select the UN Hazard Class for this material." Move the cursor to "Class 3 FLAM LIQUID" and press ENTER.

You will now see the message "Loading File ..." in the top left hand corner of your screen. From your initial responses, HAZMACS has enough information to chain to the appropriate hazard-specific KBF. This load step will take 10-40 seconds depending on your PC. When the load step is completed, the application display window will indicate that you are now in the HAZMACS Flammable and Combustible Liquids Module. Press any key to continue.

### 3.2.2 Hazard-Specific KBF Operation.

The second screen in the Flammable and Combustible Liquids Module provides a reminder that you can obtain clarification of any questions by using the "/Why" option. Press any key to continue.

The third screen is now divided into two sections. The application display window retains the previous reminder about using the "/Why" option. For our example, the query window asks "Do you know the flash point of this material?." Select "YES" and press ENTER.

The query window now asks "Within what range is this item's flash point?". Since the flash point is known to be -4 deg F cc, select "0 deg F cc or less" and press ENTER.

Next, the query window instructs you to "Select a term which appears in this item's Chemical Name or Chemical Family or Product Name". Select "Acetone" and press ENTER.

You are now asked to "Select a term which appears in this item's Proper Shipping Name". Since this information is not known, type "?."

The query window now instructs you to "Select a term which best describes the Materials to Avoid data provided for this item." Since the manufacturer advises keeping this material away from oxidizing materials, select "Oxidizers" and press ENTER.

Next, the query window asks "Do you have reason to believe that this item may exhibit more than one hazardous characteristic?". Since there is no evidence that any multiple hazards exist (e.g., flammable and poisonous liquid), select "NO" and press ENTER.

The query window now instructs you to "Select a term which best completes the phrase "Avoid exposure to ...." Since no information of this nature is available, type "?".

The next query window wants to know "Is this item packaged in limited quantities?." Since you know that there are ten 30 gal containers, select "NO" and press ENTER.

A HAZMACS display window now appears which provides the following information:

```
**********************************************************************
                  HAZMACS assigns an HCC of -

                        F2  FLAM LIQUID IMDG 3.1

              based on the following data which you provided -

                     The DOT Class is:                    Unknown
                      The UN Class is:     Class 3  FLAM LIQUIDS
           A term in the Product Name is:                 ACETONE
          A term in the Shipping Name is:                 Unknown
                   Materials to Avoid are:               OXIDIZERS
        Exposure Conditions to Avoid are:                 Unknown
        The flash point is in this range:      0 deg F cc or less

*************** (( PRESS ANY KEY TO CONTINUE )) *****************
```

After reviewing this display, press any key to continue.

HAZMACS now asks if you would like a printout of this analysis. Select either "YES" or "NO" and press ENTER.

Now the application display window informs you that this consultation is over. You are advised that if you wish to run another consultation in the "Flammable Liquids" module, select "Stay Here" in the query window. If you select "Stay Here," values for DOT Class and UN Class will remain the same. For this example, therefore, DOT Class will remain "Unknown" and UN Class will remain "Class 3 FLAM LIQUID." To change the DOT Class and/or UN Class, select "Return to Main" in the query window.

If you select "Stay Here," you are immediately returned to the CONSULT menu. Select "go" and press ENTER to begin another consultation in the Flammable and Combustible Liquids module.

If you select "Return to Main," the Main Module is automatically re-loaded requiring a wait of 10-40 seconds. During this time, the "Loading File..." message appears in the top left hand corner of your screen. When this load step is completed, the first Main Module screen appears. Press any key to begin an entirely new consultation.

## 3.3 Stopping and Suspending Work.

### 3.3.1 Quitting from the GO menu.

At any time during a consultation, you may quit by first pressing the "/" key then selecting "4Quit" from the GO menu and pressing ENTER; or you may simply type "/Q." This will return you to the CONSULT menu where you can restart the consultation. Remember, that if you are in the Main Module when you quit, you will be able to start an entirely new consultation. However, if you quit after HAZMACS has already chained to a hazard-specific module (e.g., the Flammable and Combustible Liquids Module), you will retain the DOT Hazard Class, UN Hazard Class and, in some cases, other data which was stored into the expert system's memory when you began the current consultation.

### 3.3.2 Quitting from the CONSULT menu.

You may quit from the CONSULT menu by selecting "4Quit" or by typing "Q." This will return you to the HAZMACS DOS prompt. From here you will need to type "go" to reactivate HAZMACS.

# SECTION 4. PROCESSING REFERENCE GUIDE

## 4.1 The CONSULT and GO Menus.

After the Main Module has loaded, you will see a blank green screen and the following two levels of menu options at the bottom of your screen:

```
1Help     2Go       3WhatIf    4Quit
1Help 2How? 3Why? 4Quit
```

The top four options make up the "CONSULT" menu. (Since the cursor is already on "2Go," the bottom level shows you the options that will be available on the "GO" menu).

The purpose and functions of the CONSULT menu options are as follows:

**Help** - **Calls the HAZMACS Help Facility.**

**Go** - **Starts a HAZMACS consultation.**

WhatIf - Allows you to see what would happen if one response was changed from the previous consultation. This option may be of limited benefit to the user since you must be familiar with the variable names used in the HAZMACS knowledge base files. The user is, therefore, advised to use the WhatIf option with caution. For those who wish to experiment with this option anyway, please note that only those variables that cause HAZMACS to ask a question can be changed. Generally, variables that begin with "C-" are used when HAZMACS is seeking a "yes or no" response. For example, "C-flash" is the variable whose value is sought when HAZMACS asks "Do you know the flashpoint of this material?". Variables that begin with "Qy-" are used when HAZMACS asks questions that require the user to select from a menu of options. So "Qy-flash" is the variable whose value is sought when HAZMACs asks "Within what range is this item's flash point?". The user is also cautioned that, when using the WhatIf option, HAZMACS will also seek the value of any unknown variables. So if you answered any question in the previous consultation by typing "?," those questions will be repeated in your "WhatIf" consultation.

Quit - Causes you to Quit HAZMACS. You will be returned to the DOS prompt.

Once you have begun a consultation by selecting "2Go" and pressing "ENTER," several screens of general information and instructions follow. After the third general information screen, the HAZMACS Main Module screen is divided into two sections or "windows." The top section is the "application display window." The bottom section is the "query window." Several instructions or reminders appear at the bottom of the screen. Those instructions are explained below:

⇑ ⇓ ⇒ ⇐ : Use the arrow keys to move around a menu of choices.

Enter to select: Press ENTER to "select" from a menu of choices. If only one menu selection is allowed, ENTER will also "complete" your selections.

End to complete: Press the END key to complete your selections. This applies only to those HAZMACS query menus which allow the user to make multiple selections.

/Q to Quit: You may quit a HAZMACS consultation at any time by pressing the "/" key and then selecting "Quit" on the GO menu or by simply typing "/Q." This will return you to the CONSULT menu.

? for Unknown: If the answer to a HAZMACS question is either not shown on the menu of choices or is unknown, type "?."

By pressing the "/" key during a consultation, the following menu options now appear at the bottom of your screen:

1Help 2How 3Why 4Quit

This is the "GO" menu. The purpose and functions of the GO menu options are as follows:

Help - Calls the HAZMACS Help Facility.

How - This option is of limited benefit to the user. It explains how (or why) internal HAZMACS variables were assigned their current values. However, the user must be familiar with the variable names used in the HAZMACS knowledge base files in order to obtain meaningful information. It is recommended that the user ignore this option.

Why - Tells you why a question is being asked and/or provides additional information intended to clarify the question. Also provides hints on where you might find the answer to this question.

Quit - Allows you to quit a consultation. It returns you to the Consult Menu.

You can select a command option from the CONSULT menu and/or the GO menu in one of four ways:

- Type the first letter of the command. (However, on the Go Menu, typing "H" will select the "Help" option, not the "How" option.
- Type the command number (e.g., type 1 for Help).
- Press the function key number (e.g., press F1 for Help).
- Use the arrow keys to scroll the cursor to the command and press ENTER.

## 4.2 Conventions.

### 4.2.1 The Use of Color in Displays.

When HAZMACS displays the results of its analysis, like those described in Section 3.2.2 of this manual, the window color used in the display denotes the severity or degree of hazard present. A red window color indicates a high risk hazard as in an HCC of C1 High Risk Acid. A magenta (purple) window is used to denote low risk hazards as in an HCC of C3 Low Risk Acid. A blue window color is used for two purposes. In some cases, a blue window will denote a medium or mid-range hazard as in an HCC of T4 Poison, Food Contaminant. In other cases, a blue window is used to denote multiple hazards as in an HCC of F5 Flammable and Poison Liquid.

### 4.2.2 Multiple Menus.

As was the case for DOT Hazard Class in the sample problem described in Section 3.2, it is not always possible to include all potential answers to a HAZMACS question in one query screen. In such cases, the words "First of two screens" are shown at the top of the query window. By typing "?," the user is shown the second screen of possible answers.

### 4.2.3 Multiple Menu Selections.

HAZMACS often allows the user to make more than one selection from a menu of choices. This convention is typically used for answering questions pertaining to incompatibility (materials to avoid) and reactivity (conditions to avoid). When the HAZMACS query window indicates that the user may "Select up to two" or "Select up to three," you may make your selections by pressing the ENTER key and then enter or complete your selections by pressing the END key.

## 4.3 Help Facility.

The HAZMACS Help Facility may be accessed by selecting "1Help" from either the CONSULT menu or the GO menu. The Help Facility provides useful information pertaining to starting, running and quitting a consultation. The CONSULT and GO menus are described and explained and instructions are provided for moving the cursor, selecting from a menu of choices, and so forth. The Help Facility provides information on the following topics:

CONSULT MENU
GO MENU
SELECTING MENU OPTIONS
GIVING GO COMMANDS
USING "?" FOR UNKNOWN

For each topic, closely related topics are identified. So, for instance, if you are currently viewing the Help Facility for the CONSULT MENU, the top of that screen will look like this:

CONSULT MENU

Related: GO MENU SELECTING MENU OPTIONS LIST OF TOPICS

Then, by moving the cursor to the desired related topic and pressing enter, you will be able to view the Help Facility for the GO MENU or SELECTING MENU OPTIONS or you may view the complete LIST OF TOPICS.

## 4.4 Error Messages.

It may be possible to stump HAZMACS. This may occur if the user has provided HAZMACS a combination of responses for which there is no decision rule in the HAZMACS knowledge base. In such instances, HAZMACS will automatically ask "What is the value of (name)?" where "name" is the variable whose value HAZMACS is unable to determine. If this situation occurs, the user is advised to quit the current consultation and start a new consultation after thoroughly reviewing the data provided to HAZMACS.

The user should never accept an HCC assignment from HAZMACS if the question "What is the value of (name)?" was asked during the consultation. Any problems of this nature should be brought to the attention of one or more of the organizations identified in Section 2.3 of this manual so that the HAZMACS knowledge base can be corrected.

# SECTION 5. HAZARDOUS CHARACTERISTIC CODES

| HCC | Hazard Group | Abbreviated Hazard Group |
|---|---|---|
| A1 | Radioactive, Licensable | RAM LICENSABLE |
| A2 | Radioactive, Licensable, Low Risk | RAM LICENSABLE LOW RISK |
| A3 | Radioactive, License Exempt | RADIOACTIVE EXEMPT |
| A4 | Radioactive, License Exempt, Authorized | RADIOACTIVE EXEMPT OATH |
| C1 | Corrosive, DOT, Acid | CORROSIVE DOT ACID |
| C2 | Corrosive, DOT, Alkali | CORROSIVE DOT ALKALI |
| C3 | Acid, Low Risk | ACID LOW RISK |
| C4 | Alkali, Low Risk | ALKALI LOW RISK |
| D1 | Oxidizer | OXIDIZER |
| D2 | Oxidizer, Low Risk | OXIDIZER LOW RISK |
| D3 | Oxidizer and Poison | OXIDIZER POISON |
| D4 | Oxidizer and Corrosive | OXIDIZER CORR |
| E1 | Explosive, Military | EXPLOSIVE MILITARY |

SECTION 5. HAZARDOUS CHARACTERISTIC CODES (Cont'd)

| HCC | Hazard Group | Abbreviated Hazard Group |
|---|---|---|
| E2 | Explosive, Low Risk | EXPLOSIVE LOW RISK |
| F1 | Flammable, Aerosol | FLAM AEROSOL |
| F2 | Flammable, IMDG 3.1 | FLAM IMDG 3.1 |
| F3 | Flammable, IMDG 3.2 | FLAM IMDG 3.2 |
| F4 | Flammable, IMDG 3.3 | FLAM IMDG 3.3 |
| F5 | Flammable and Poison | FLAM POISON |
| F6 | Flammable and Corrosive | FLAM CORROS |
| F7 | Flammable Solid | FLAM SOLID |
| F8 | Combustible, Liquid | COMBUST LIQUID |
| G1 | Gas, (Non Flammable) Poison | GAS, POISON |
| G2 | Gas, Flammable, Non Toxic | GAS, FLAM, NON TOX |
| G3 | Gas, Non Flammable, Non Toxic | GAS, NON FLAM, NON TOX |
| G4 | Gas, Non Flammable, Oxidizer | GAS, NON FLAM, OXIDIZ |
| G5 | Gas, Non Flammable, Corrosive | GAS, NON FLAM, CORROS |
| G6 | Gas, Non Flammable, Poison, Corrosive | GAS, NF, POISON, CORROS |
| G7 | Gas, Non Flammable, Poison, Oxidizer | GAS, NF, POISON, OXIDIZ |
| G8 | Gas, Flammable, Poison | GAS, POISON, FLAM |
| G9 | Gas, Non Flammable, Poison, Corrosive, Oxidizer | GAS, NON FLAM, P, C, O |
| J1 | Miscellaneous Flammable Liquids | MISC FLAM LIQUID |
| J2 | Miscellaneous Flammable Solids | MISC FLAM SOLID |
| J3 | Miscellaneous Oxidizers | MISC OXIDIZERS |
| J4 | Miscellaneous Organic Peroxides | MISC ORG PEROXIDE |
| J5 | Miscellaneous Poisons | MISC POISON |
| J6 | Miscellaneous Corrosive | MISC CORROSIVE |
| J7 | Miscellaneous UN Class 9 | UN CLASS 9 |
| J8 | Miscellaneous ORM-E | MISC ORM-E |
| K1 | Infectious Substance | INFECTIOUS SUB |
| K2 | Cytotoxic Drugs | CYTOTOXIC DRUG |
| M1 | Magnetized Material | MAGNETIZED MATERIAL |
| N1 | Non Hazardous | NON HAZARDOUS |
| P1 | Peroxide, Organic, Regulated | PEROXIDE ORG US DOT |
| P2 | Peroxide, Organic, Low Risk | PEROXIDE ORG LOW RISK |
| R1 | Reactive Chemical, Flammable | REACTIVE CHEM FLAM |
| R2 | Water Reactive Chemical | WATER REACTIVE CHEM |
| T1 | DOT Poison-Inhalation Hazard | DOT POISON INHALE |
| T2 | UN Poison, Packing Group I | UN POISON GROUP I |
| T3 | UN Poison, Packing Group II | UN POISON GROUP II |
| T4 | Poison, Food Contaminant | POISON FOOD CONTAM |
| T5 | Pesticide, Low Risk | PESTICIDE LOW RISK |
| T6 | Health Hazard | HEALTH HAZARD |
| T7 | Carcinogen | CARCINOGEN |
| W1 | Marine Pollutant | MARINE POLLUTE SECTION |

## SECTION 6. TERMS AND ABBREVIATIONS USED IN THIS MANUAL.

### 6.1 Computer Hardware and Software Terms and Abbreviations.

**Application Disk** - the disk which was provided to you with this manual which contains all of the files and programs needed to install and run HAZMACS.

**Chaining** - the process by which the HAZMACS Main Module accesses another hazard-specific knowledge base file (e.g., corrosives, flammable liquids). Also, at the end of a consultation, the user may elect to chain back to the Main Module.

**Co-resident programs** - two or more computer programs which simultaneously occupy RAM disk space.

**Consultation** - a single session with HAZMACS resulting in an HCC assignment or a determination that no code assignment can be made.

**Consult Menu** - the first menu displayed after loading HAZMACS. Selecting "Go" from the Consult Menu starts a consultation. Quitting from the Consult Menu returns the user to the DOS prompt.

**DOS** - Disk Operating System

**Expert System** - computer programs which emulate a human expert's problem solving processes.

**Go Menu** - the second menu displayed after loading HAZMACS. During a consultation, the Go Menu is accessed by pressing the "/" key. Quitting from the Go Menu returns the user to the "Consult Menu."

**KBF** - Knowledge base file.

**PC** - Personal computer.

**RAM** - Random access memory. RAM is the "working" memory area of a computer which is not saved when the computer is turned off.

### 6.2 Other Terms and Abbreviations Used in This Manual.

**DOT Hazard Class** - the classification given to hazardous material by the U.S. Department of Transportation.

Flash point - the minimum temperature at which a substance gives off flammable vapors which, in contact with a spark or flame, will ignite.

MSDS - Material Safety Data Sheet.

Packaging Group - a form of hazardous material classification consisting of three categories. Items in Packing group I are considered to be "major" transportation hazards. Packing group II items are considered to be "medium" transportation hazards. Packing group III items are considered to be "minor" hazards.

pH - the "potential of Hydrogen" is a measure of the acidity or alkalinity of a corrosive liquid. The pH is measured on a scale of 0 to 14 with 0 being most acidic, 14 being most alkaline and 7 being neutral.

UN Hazard Class - the classification given to hazardous materials by international regulators of transportation such as the International Air Transport Association (IATA).

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The Depot Operations Division of the Defense Logistics Agency (DLA) is implementing a new hazardous material classification system consisting of 55 Hazardous Characteristic Codes (HCC). The HCC will provide critical information needed to effectively manage, store and ship hazardous materials. With implementation of new automated DLA Warehousing and Shipping Procedures (DWASP), DLA depot receiving personnel will be required to assign the HCC if it is missing from pertinent documents. Without the HCC, the DWASP system will not assign a depot storage location. Because the new HCC must be assigned quickly and accurately, an expert systems approach offers a feasible and practical means for providing this support. Accordingly, the Hazardous Material Analysis and Coding System (HAZMACS) was developed. HAZMACS is a PC-based expert system which queries the user about the known characteristics of suspected hazardous material and assigns an HCC based on the user's responses. HAZMACS consists of a main knowledge base file which "chains" to any of 13 other hazard-specific knowledge base files. The expert system was developed with the VP-Expert software package and has more than 2,200 rules.

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